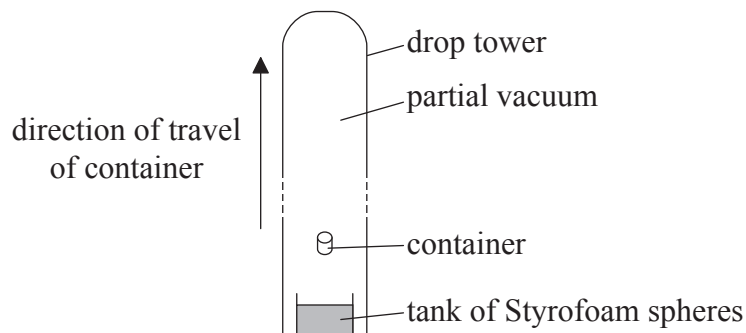


Answer **all** questions. Write your answers in the boxes provided.

1. In the drop tower shown, containers with experiments inside of them are fired upwards inside a vertical tower.



The container moves under the influence of gravity and eventually falls back to the bottom of the tower. Most of the air is removed from the tower so that air resistance is negligible. While in flight, the container and its contents are in free-fall.

- (a) The container is fired vertically upwards with initial speed 48 m s^{-1} . Determine the time that the container is in flight. [2]

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(Question 1 continued)

- (b) At the end of the flight, the container of total mass 480 kg falls into a tank of expanded Styrofoam (polystyrene) spheres to slow it. The container stops after moving a distance of 8.0 m in the Styrofoam. Calculate the average force that acts on the container due to the spheres. [3]

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- (c) Outline why the experiments inside the container could be considered to be in “weightless” conditions. [2]

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(Question 1 continued)

(d) The tower is 120 m high with an internal diameter of 3.5 m. When most of the air has been removed, the pressure in the tower is 0.96 Pa.

(i) Determine the number of molecules of air in the tower when the temperature of the air is 300 K. [3]

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(ii) Outline whether the behaviour of the remaining air in the tower approximates to that of an ideal gas. [2]

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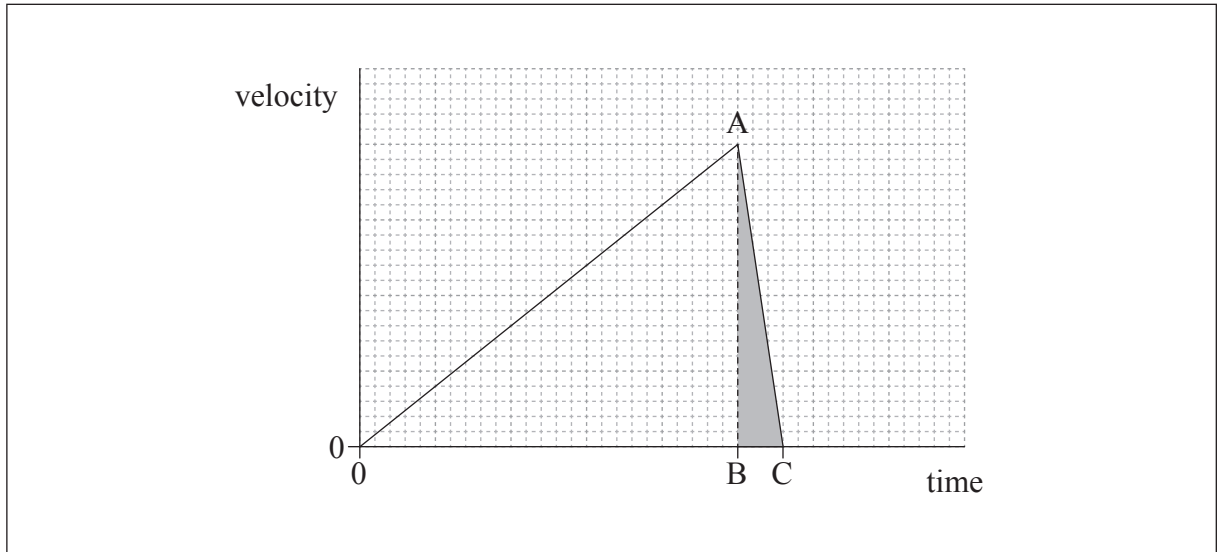
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(Question 1 continued)

- (e) The container can also be released from rest at the top of the tower. The graph shows how the container velocity varies with time from release with the tower in a partial vacuum.



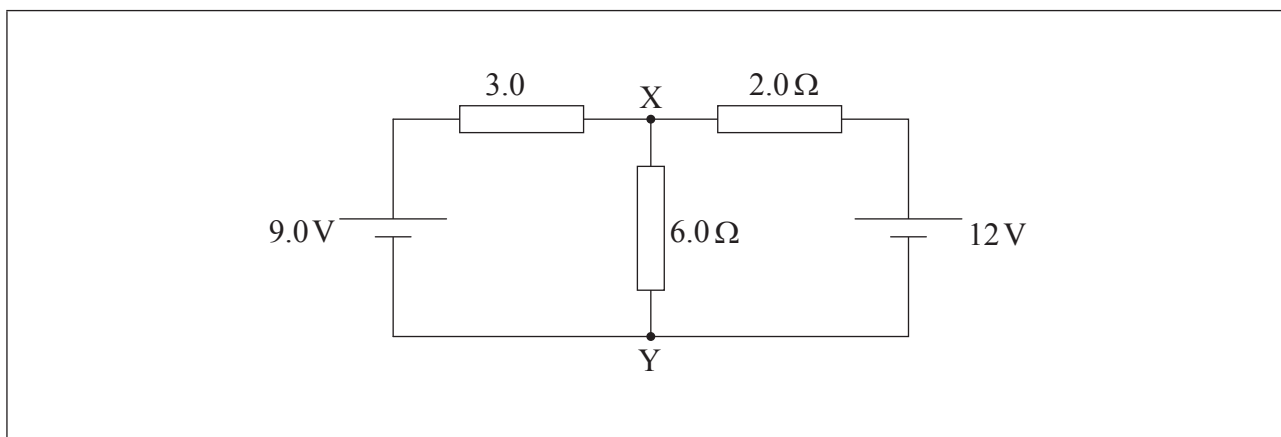
- (i) State the quantity that is represented by the shaded area ABC. [1]

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- (ii) Air is introduced into the tower. The container is released from the top of the tower when the air in the tower is at atmospheric pressure. Using the axes in (e), sketch a graph to show how the container velocity varies with time from release when the air is at atmospheric pressure. [3]



2. The diagram shows an electrical circuit with the values of its components. The cells have a negligible internal resistance.



- (a) Show, using Kirchhoff's laws, that the current in the $6.0\ \Omega$ resistor is 1.5 A.

[4]

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(Question 2 continued)

- (b) (i) Calculate the potential difference between X and Y.

[1]

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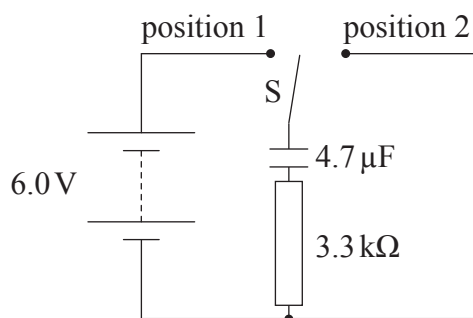
- (ii) Outline whether X **or** Y is at higher potential.

[1]

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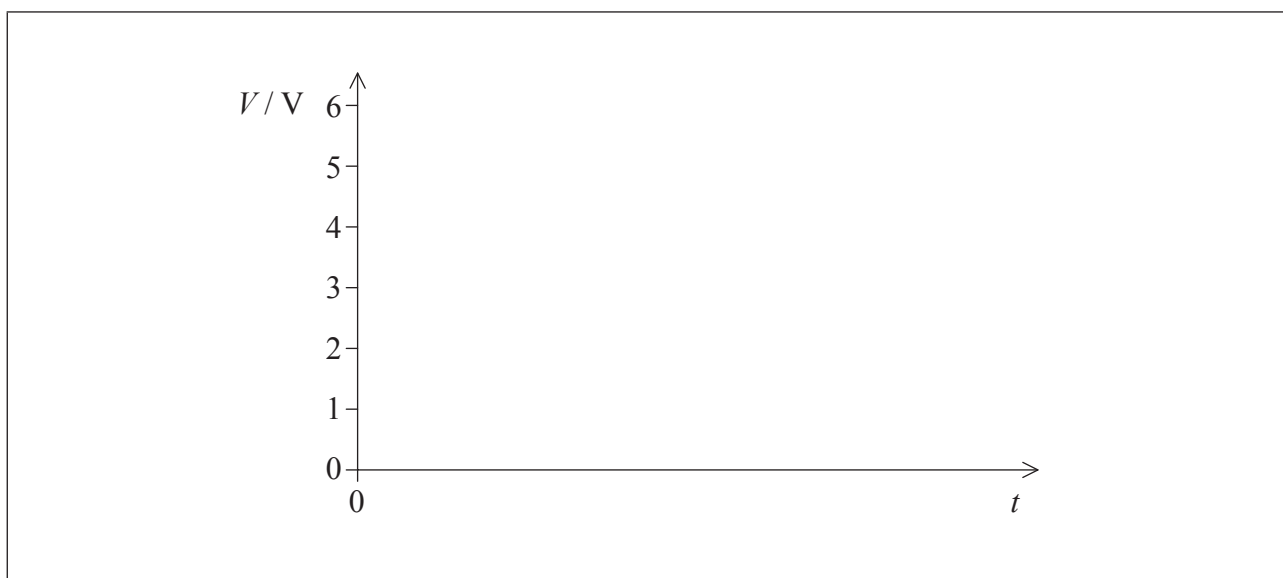
3. A circuit is designed to supply regular pulses of charge to a $3.3\text{ k}\Omega$ resistor using an electronic switch S.



Initially the capacitor is uncharged. The battery has a negligible internal resistance. The capacitance of the capacitor is $4.7\text{ }\mu\text{F}$.

- (a) At time $t=0$ the switch is moved to position 1. Using the axes, draw a graph to show how the potential difference V across the capacitor varies with time t as it charges. A time scale is not required.

[2]



(This question continues on the following page)



(Question 3 continued)

(b) A single pulse of charge is produced by moving the switch S to position 2 for 6.3 ms.

- (i) Show that the potential difference across the capacitor falls by about 2 V during the duration of the pulse. [3]

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- (ii) Calculate the charge that flows through the circuit during the pulse. [2]

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- (iii) The battery has a charge capacity of 0.55 Ah and the circuit produces one pulse each second. Calculate the time, in years, for which the battery can operate the circuit. [2]

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(Question 3 continued)

- (iv) Two batteries in series, each of emf 6.0 V and having negligible internal resistance, replace the single battery. All other components in the circuit remain the same. Compare the energy transferred from the two batteries with the energy transferred from the single battery during one charge–discharge cycle. [2]

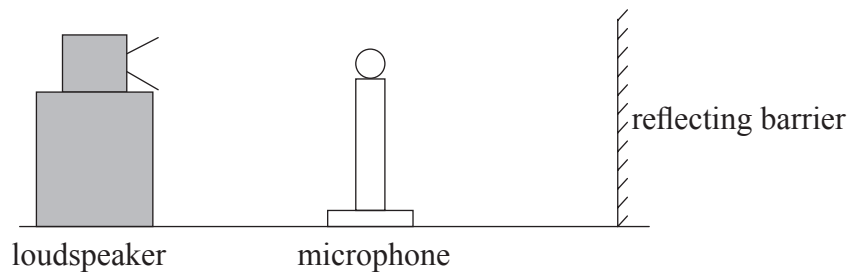
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4. A loudspeaker emits sound waves of a single frequency towards a reflecting barrier.



A microphone is moved along a straight line between the loudspeaker and the barrier. A sequence of equally spaced maxima and minima of sound wave intensity is detected.

- (a) Explain how the maxima and minima are formed. [4]

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(This question continues on the following page)



(Question 4 continued)

- (b) The microphone is moved through 1.0 m from one point of minimum intensity to another point of minimum intensity. It passes through seven points of maximum intensity as it moves. The speed of sound is 340 m s^{-1} .

- (i) Calculate the wavelength of the sound waves.

[2]

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- (ii) Outline how you could use this arrangement to determine the speed of sound in air.

[3]

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5. (a) A power station burns natural gas at a rate of 35 kg s^{-1} . The power output of the station is 750 MW and the efficiency of the station is 38 %.

- (i) Calculate the energy provided by the natural gas each second. [1]

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- (ii) Calculate the specific energy of the natural gas. State appropriate units for your answer. [3]

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- (b) Outline why much of the world's energy is provided from fossil fuels. [2]

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(This question continues on the following page)



(Question 5 continued)

(c) There is a suggestion that the temperature of the Earth may increase if the use of fossil fuels is not reduced over the coming years.

(i) Explain, with reference to the enhanced greenhouse effect, why this temperature increase may occur. [3]

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(ii) Outline how scientists continue to attempt to resolve the climate change debate. [1]

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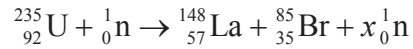
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(Question 5 continued)

- (d) Nuclear power stations are one way in which energy can be generated without the use of fossil fuels. One example of a nuclear fission reaction is as shown.



- (i) Identify the value of x . [1]

- (ii) The following data are available.

Mass of U-235 = 235.044 u
 Mass of n = 1.009 u
 Mass of La-148 = 148.932 u
 Mass of Br-85 = 84.910 u

Determine, in MeV, the energy released when one uranium nucleus undergoes nuclear fission in the reaction in (d). [3]

(This question continues on the following page)



(Question 5 continued)

- (iii) Outline, with reference to the speed of the neutrons, the role of the moderator in a nuclear reactor.

[3]

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6. In 1798, Cavendish investigated Newton's law of gravitation by measuring the gravitational force between two lead spheres.

(a) State Newton's law of gravitation.

[2]

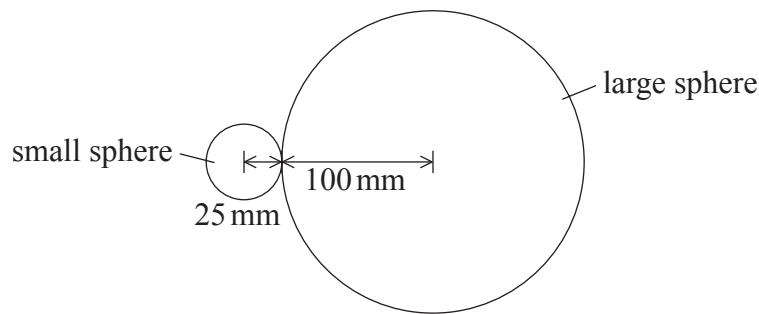
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- (b) A student repeats the experiment with modern apparatus that has lead spheres of unequal size.



(not to scale)

The large sphere had a radius of 100 mm and a mass of 47 kg. The small sphere had a radius of 25 mm and a mass of 0.73 kg.

- (i) Estimate the gravitational force between the spheres when the spheres were in contact.

[2]

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(This question continues on the following page)



(Question 6 continued)

- (ii) The student repeats Cavendish’s experiment using lead spheres with twice the radius. Discuss the effect on your calculation in (b)(i) of doubling the radius of both spheres. [4]

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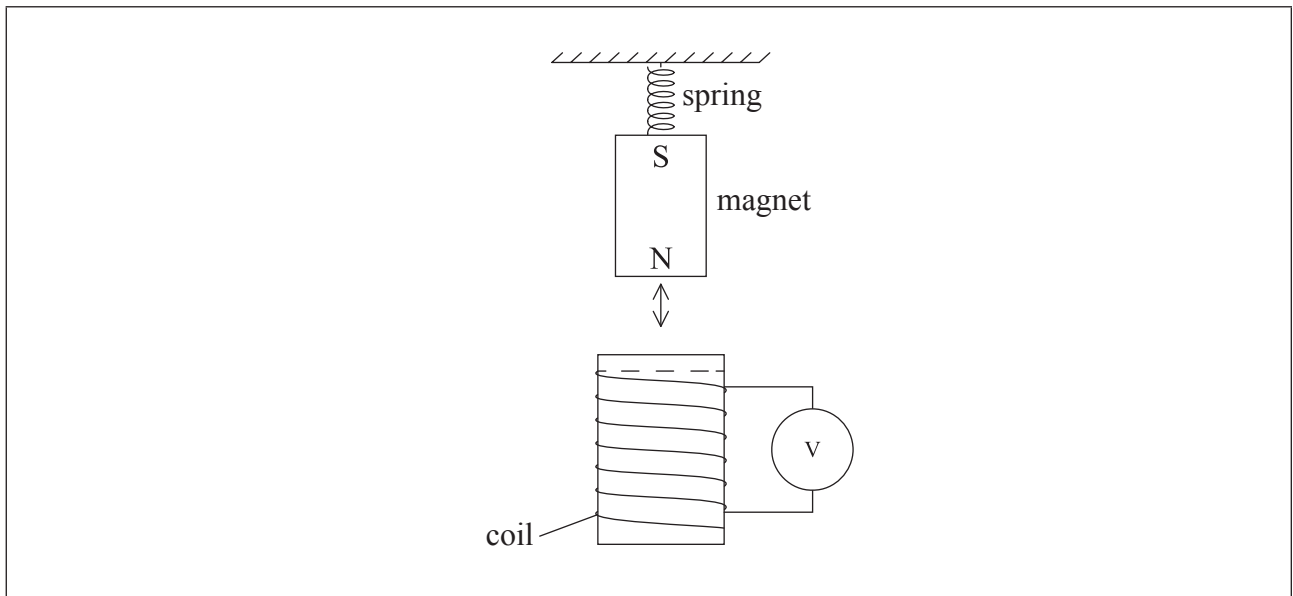
- (c) In Cavendish’s original experiment, the large sphere was part of an isochronous pendulum. State what is meant by isochronous. [1]

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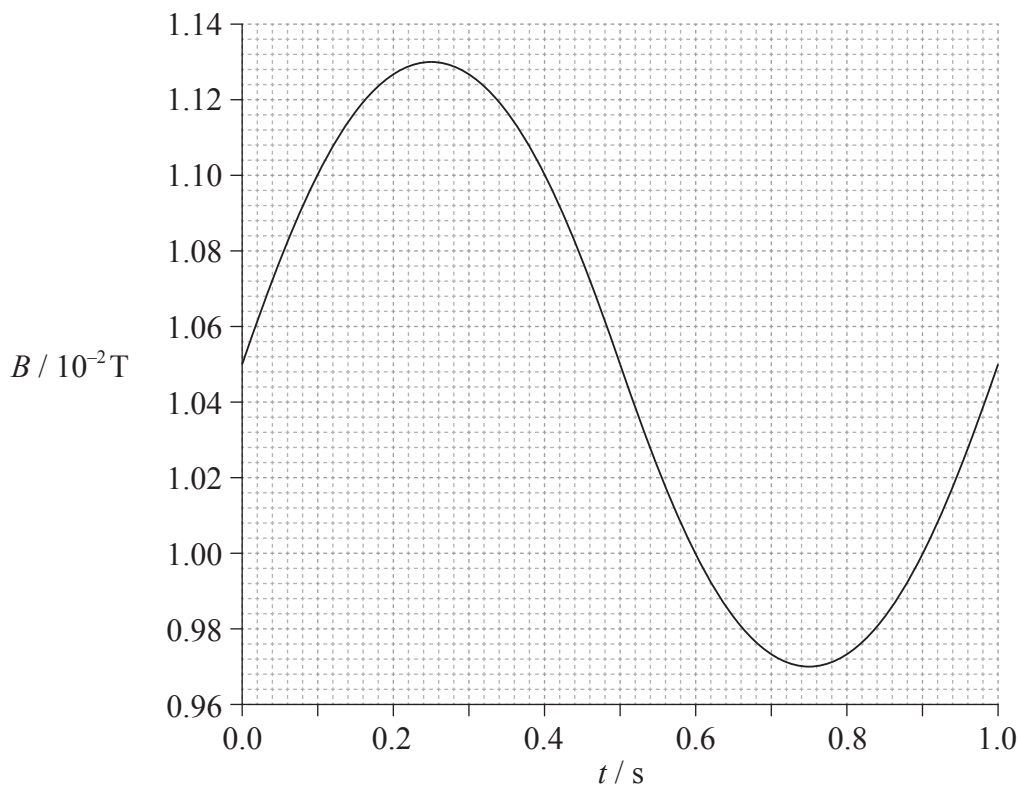


7. A magnet is suspended on the end of a spring and oscillates vertically with a small amplitude above a coil.



The coil has 240 turns each with a cross-sectional area of $2.5 \times 10^{-4} \text{ m}^2$.

The graph shows how the magnetic flux density B through the coil varies with time t for one complete oscillation of the magnet. The magnet is at its equilibrium position when $t=0$.



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(Question 7 continued)

- (a) Determine the maximum electromotive force (emf) induced in the coil.

[4]

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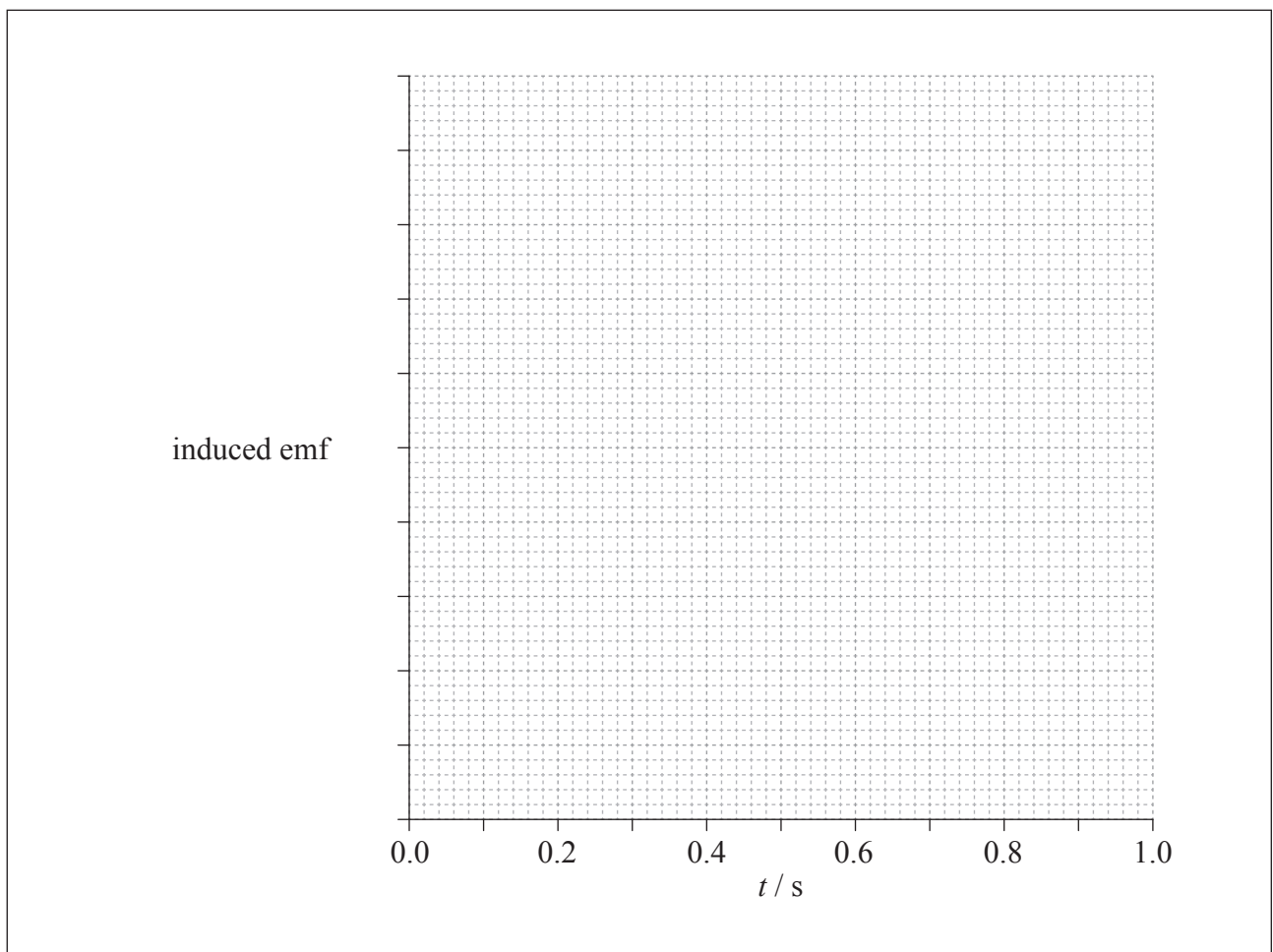
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- (b) The spring is changed so that the frequency of oscillation of the magnet is doubled without changing the amplitude of oscillation. Using the axes, sketch a graph to show how the induced emf in the coil varies with time t when the frequency of oscillation has doubled. The coil is at its equilibrium position when $t=0$. You should give suitable values on the y -axis.

[3]



(This question continues on the following page)



Turn over

(Question 7 continued)

- (c) (i) Label the diagram of the magnet and coil on page 18 with arrows to show the direction of the conventional current as the north pole of the magnet approaches the coil. [1]

- (ii) Explain your answer to (c)(i). [2]

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Turn over

8. (a) Outline what is meant by gravitational field strength.

[2]

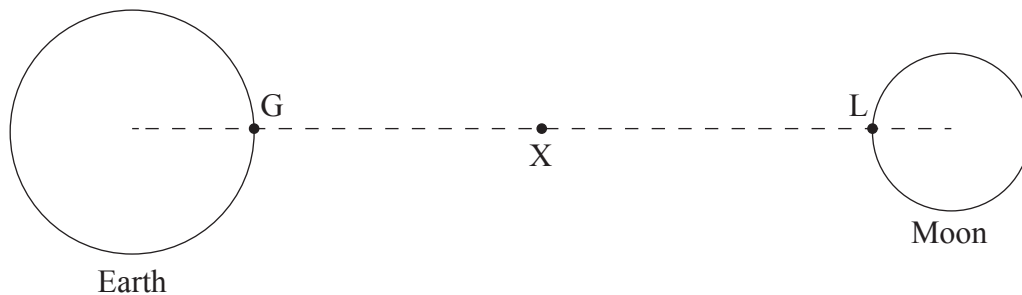
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- (b) X is a point on the line that joins the centre of the Earth and the centre of the Moon. At X, the resultant gravitational field strength of the Earth and the Moon is zero.



The following data are available.

Mass of the Earth	$= 6.0 \times 10^{24} \text{ kg}$
Mass of the Moon	$= 7.3 \times 10^{22} \text{ kg}$
Radius of the Moon	$= 1.7 \times 10^6 \text{ m}$
Distance from the centre of the Earth to the surface of the Moon	$= 3.7 \times 10^8 \text{ m}$

- (i) Determine the ratio $\frac{\text{distance of X from centre of the Earth}}{\text{distance of X from centre of the Moon}}$.

[2]

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(Question 8 continued)

- (ii) Calculate, using the data, the total gravitational potential at the surface of the Moon due to the Earth and Moon. [3]

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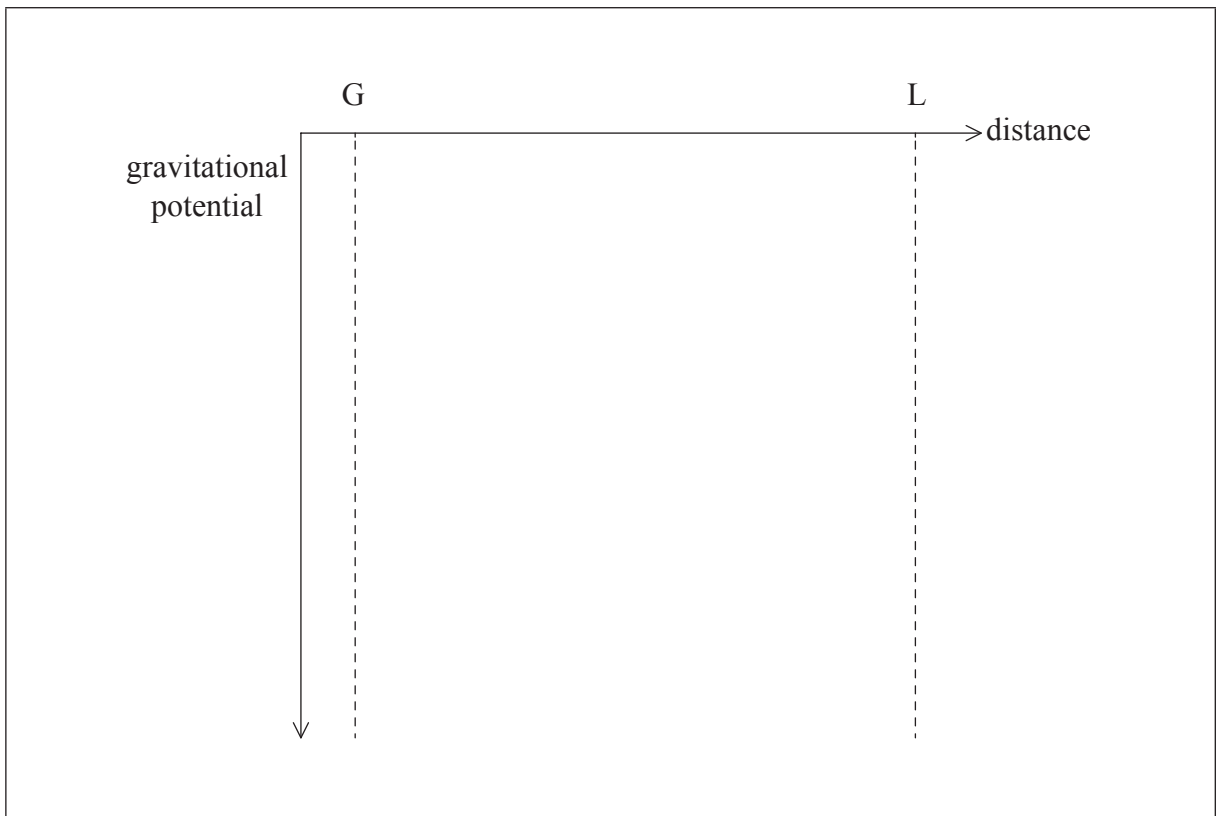
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- (iii) G is a point on the surface of the Earth and L is a point on the surface of the Moon. Using the axes, sketch a graph to show how the total gravitational potential varies with distance from G to L. [3]



9. An electron and a positron can be created through pair production when a photon interacts with a nucleus.

- (a) Explain why there is a photon frequency below which an electron–positron pair cannot be created. [2]

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- (b) Calculate the minimum photon frequency for the production of an electron–positron pair. [3]

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- (c) Outline why a nucleus must be involved in the interaction. [2]

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